SIGGRAPH 2002
SAN ANTONIO

Recreating the Past

Alan Chalmers   Kate Devlin
Paul Debevec   Philippe Martinez
Duncan Brown   Greg Ward

SIGGRAPH 2002
SAN ANTONIO

Recreating the Past

Realistic Lighting Simulation
Greg Ward

The Three Steps of Lighting Simulation

1. Model Generation
2. Simulation / Rendering
3. Visualization

---

1. Model Generation

Determine the Accuracy Required
- Tape Measure or Laser Scanner?
- Macbeth Chart or Spectrophotometer?
- Aerial Photo or Site Survey?

Tape Measure or Depth Scanner?

Tape Measure Requirements and Accuracy
- Digital camera and an assistant (both optional)
- Centimeter accuracy

Depth Scanner Requirements and Accuracy
- Scanner + computer + set-up + data reduction
- Millimeter accuracy

Tape Measure Example

- Accident Reconstruction (recent archaeology)
- Needed to know driver's eye height
- Photo with tape measure followed by computer modeling
- Centimeter accuracy

Depth Scanner Example

- **Pietà Project**
  www.research.ibm.com/pieta
- **Multi-baseline stereo camera with 5 lights**
- **Captured geometry and reflectance**
- **Sub-millimeter accuracy**

Macbeth Chart or Spectrophotometer?
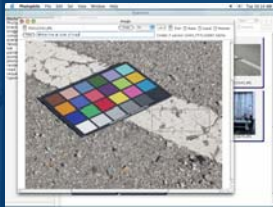
Macbeth Chart Requirements and Accuracy
- ColorChecker™ chart and a digital camera
- Accurate to about 8 ΔE (1994 CIE Lab)

Spectrophotometer Requirements and Accuracy
- Hand-held spectrophotometer
- Accurate to about 1 ΔE

Macbeth Chart Example

- **Digital photo with ColorChecker™ under uniform illumination**
- **Compare points on image and interpolate**
- **Best to work with HDR image**
- **Accurate to ~ 8 ΔE**

Spectrophotometer Example

- **Commercial spectrophotometers run about $5K**
- **Measure reflectance spectrum for simulation under any light source**
- **Accurate to ~ 1 ΔE**

Aerial Photo or Site Survey?

Aerial Requirements and Accuracy
- Satellite photos or (better) fly-over
- 1-10 meter accuracy, usually without elevation

Site Survey Requirements and Accuracy
- GPS or traditional surveying equipment
- 1-10 centimeter accuracy, with elevation

Aerial Photo Example

- **Giza Pyramids**
- **Fly-over aerial photo shows positions of pyramids and tombs**
- **Requires perspective correction**
- **Accuracy is ~ 5 m**

Site Surveying

- **Traditional instruments measure point-to-point**
- **GPS equipment measures absolute position**
- **Accuracy 1-10 cm**

---

2. Simulation / Rendering

- *Radiance* **Input Requirements**
- **Rendering Time and Accuracy**
- **Output Options**

Radiance Input Requirements

- *Radiance* **is a physically-based lighting simulation and rendering tool from LBNL**
- **Takes geometry and RGB reflectances (also BRDFs, procedural textures, etc.)**
- **Prefiltering with source illuminant yields accurate colors (~ 2 ΔE)**
- **Give attention to source photometry!**

Example *Radiance* Image

Rendering Time and Accuracy

- **Diffuse interreflection and output resolution are the main parameters**
- **Many other parameters controlling time and accuracy of direct, specular, etc.**
- **User-friendly front-end program called "rad" is handy to control rendering**

Rad Parameter Settings

Rad Variable Settings			
Variable Name	Interpretation	Legal Values	Affects
DETAIL	geometric detail	High, Med, Low	image sampling, irradiance value density
EXPOSURE	picture exposure	positive real	final picture brightness, ambient approximation
INDIRECT	importance of indirect diffuse contribution	0, 1, 2,...	number of diffuse interreflections
PENUMBRAS	importance of soft shadows	True, False	source subdivision, source sampling, image plane sampling
QUALITY	rendering quality/accuracy	High, Med, Low	nearly everything
VARIABILITY	light distribution in the space	High, Med, Low	indirect irradiance interpolation, hemisphere sampling
ZONE	region of interest	Interior/Exterior keyword plus bounding box	irradiance value density, standard viewpoints

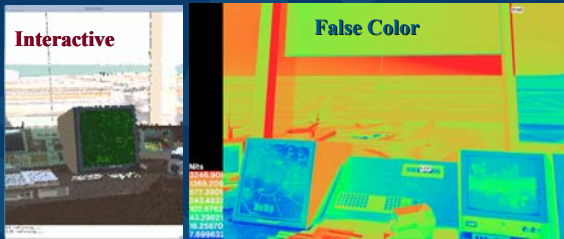## Rendering Quality Comparison

| 7 seconds | 1.5 minutes | 2 hours |

Output Options

- *Radiance* picture format is gaining popularity in HDR imaging
  - 4-byte RGBE uses common exponent per pixel
  - XYZE format for photometric images
  - Converters to and from other formats, including LogLuv TIFF
- **Interactive rendering for previewing**
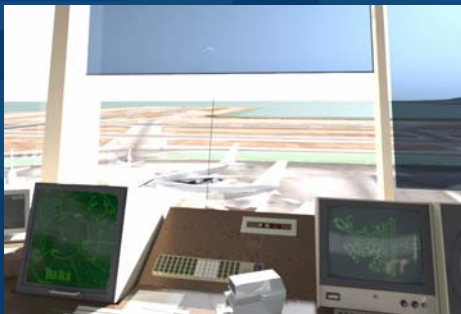- **Direct numerical output is also supported**
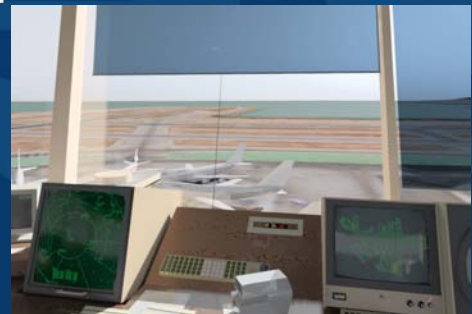

3. Visualization

- **Numerical Visualization**
  - False color images and plots
  - Visibility analysis - how well could people see?
- **Tone-mapping**
  - Visibility-matching tone operator
- **High Dynamic Range Display**
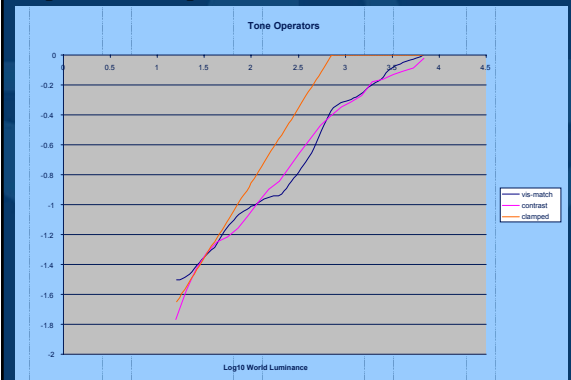
Tone-mapping Goal: Colorimetric

Tone-mapping Goal: Optimize Contrast

# Tone-mapping Goal: Match Visibility

Operator Comparison

# Visibility-matching Tone-mapping Approach

- **Generate histogram of log luminance**
- **Redistribute luminance to fit output range**
- **Optionally simulate human visibility**
  - match contrast sensitivity
  - scotopic and mesopic color sensitivity
  - disability (veiling) glare
  - loss of visual acuity in dim environments
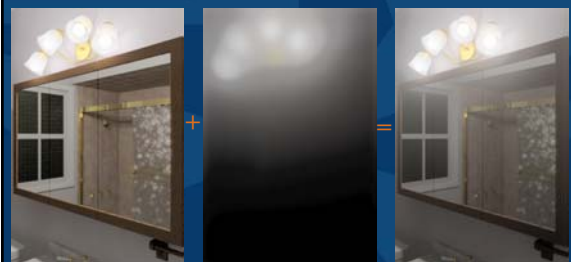
Histogram Adjustment

Result
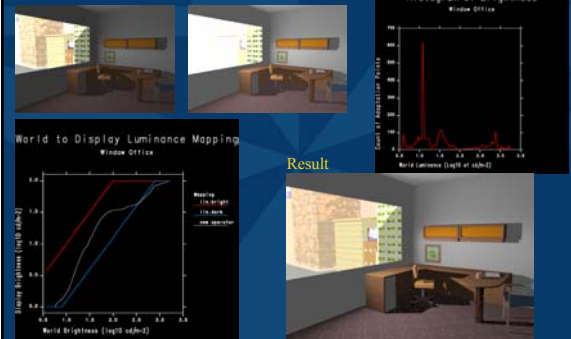
Contrast & Color Sensitivity

From Ferwerda et al, SIGGRAPH '96

From Larson et al, TVCG '97
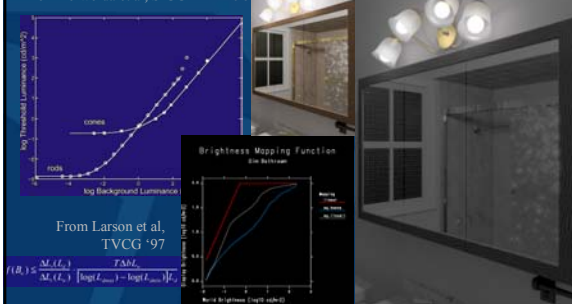
Veiling Glare Simulation

High Dynamic Range Projection

- **TI Micro-mirror Device**
  - Good dynamic range, tunable gamut
  - Widely used for still projection systems
  - Already in trials for digital cinema
- **Silicon Light Machines Grating Light Valve**
  - Amazing dynamic range, widest gamut
  - Still in development
  - Promising for digital cinema

High Dynamic Range Display

- **UBC Structured Surface Physics Lab LCD-based HDR Display**
  - 1024x768 resolution
  - 60,000:1 dynamic range
  - 2,000 cd/m^2 maximum luminance
- **Next generation planned**
  - 2048x1536 resolution
  - 70,000:1 DR and 30,000 max. luminance

High Dynamic Range Viewer

Further Reference

- **viz.cs.berkeley.edu/gwlarson**
  - publication list with online links
  - LogLuv TIFF pages and images
- **www.debevec.org**
  - publication list with online links
  - *Radiance* RGBE images and light probes
- **radsite.lbl.gov/radiance**
  - *Radiance* rendering software and links